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October 18, 2004

Dr. Harin Ullal, MS3212
National Center for Photovoltaics
National Renewable Energy Laboratory
1617 Cole Blvd
Golden, CO 80401

Re: Thirty-fourth Monthly Report #NDJ-2-30630-11

Dear Harin,

This letter comprises the monthly technical status report for ITN's subcontract # NDJ-2-30630-11, "Plasma-Assisted Coevaporation of S and Se for Wide Band Gap Chalcopyrite Photovoltaics", under the Thin Film Partnership Program. The reported work was performed during the tenth month of phase 3 for this contract (thirty-third month overall), which is September 7, 2004 through October 7, 2004. This report describes activities performed by ITN, as well as those performed by lower-tier subcontractor Colorado School of Mines (CSM), under the direction of Dr. Colin Wolden.

## 1. Program Goals and Approach

Our primary objective under this program is to determine if the chalcogen in CIGS co-evaporation can be delivered more effectively by activation with a plasma. Possible advantages of plasma-assisted co-evaporation (PACE) are

- increased utilization of chalcogens,
- decreased deposition temperatures,
- decreased deposition times, and
- increased ability to tailor S/Se ratio.

University researchers at CSM are developing and testing the fundamental chemistry and engineering principles. Industrial researchers at ITN are adapting PACE technology to CIGSS co-evaporation and validating PACE process for fabrication of thin film PV. $In_2Se_3$ films, which are used as precursor layers in high-efficiency CIGS depositions, were used as the first test case for the examining the advantages of PACE listed above, and significant advantages were demonstrated. Presently, the examination is being extended to the complete high-efficiency three-stage CIGS co-evaporation process.

## 2. Incorporation of PACE Sources Into Three-Stage Deposition

This month, plasma-activation of Se was performed for several CIGS co-evaporations. It was found that

- The IR sensor usually used for endpoint detection is responding either to RF or light from the plasma. Shielding reduced the magnitude of the noise, but not sufficiently. The resulting films were therefore off-composition. Since the system lamps and thermocouples have not been affected by the RF, in future depositions a lamp-power method of endpoint detection[1] will be attempted. Endpoint detection is particularly important for these depositions, as background Ar from the plasma causes false emission in the EIES filament, thus preventing use of the EIES rate monitor when the plasma is ignited.
- After re-filling the Se sparger, Se pellets should be melted and then cooled before attempting deposition. Otherwise, spitting Se into the quartz ICP tube causes the tube to coat.
- Slight variations in the dimensions of the hand-blown quartz tubing can make a difference in how easily the plasma is ignited. A shorter neck and body on the tube is preferable. Other modifications to consistently enable straightforward plasma ignition may also be necessary.

Next month the above changes will be implemented to make plasma-activated CIGS films at reduced temperatures.

## 3. Film Kinetics Studies

The formation of $In_2S_3$ by co-evaporation of In and plasma-activated $H_2S$ was performed for the first time at CSM this month. This examination will quantify advantages of plasma activation to substrate temperature and S-to-In flux requirements. Work is ongoing to fully characterize phase, optical properties, thickness, and composition as a function of variations in S-to-In flux and substrate temperature.

## 4. Publications and Team Activities

Manuscripts for the *Journal of Vacuum Science and Technology A* and the upcoming fall NREL SET meeting were completed and submitted. Oral and poster presentations associated with those manuscripts are also being prepared.

ITN and CSM participate in CIS team activities. This month, revisions suggested by other authors to a paper describing absorber sub-team activities were used to form a second draft, and it was distributed to all participants for review. Comments on the second draft will be received until October 20. Then, the paper will undergo its final revisions and be submitted to a journal in early November.

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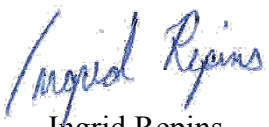
[1] Kessler J, Scholdstrom J, Stolt L. Rapid Cu(In,Ga)$Se_2$ Growth Using "End Point Detection. *Proceedings of the 28th IEEE Photovoltaics Specialists Conference,* 2000; 509-512.

Best Wishes,



Ingrid Repins
Principal investigator
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Cc: Ms. Carolyn Lopez; NREL contracts and business services
Dr. Colin Wolden; CSM technical lead